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# Earth Temperatures at Cardiff, Long Ashton and Ross-on-Wye

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Departures from average of 1 foot earth temperatures for Cardiff and Ross-on-Wye are used to represent areal values in SE Wales in the Weekly Weather Summary for the Welsh Region of N.A.A.S. The 1931-60 averages and standard deviation for these two stations are:-

| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | CARDIFF | | | | | | | |
| Mean | 4.7 | 4.6 | 5.8 | 9.0 | 12.3 | 15.7 | 17.4 | 17.2 | 15.2 | 11.9 | 8.5 | 6.2 | 10.7 °C |
| S.D. | 1.2 | 1.3 | 1.3 | 0.9 | 0.9 | 0.9 | 1.0 | 0.8 | 0.8 | 0.9 | 0.9 | 1.4 | 0.5 |
| | | | | | | ROSS-ON-WYE | | | | | | | |
| Mean | 4.3 | 4.2 | 5.8 | 8.9 | 12.2 | 15.6 | 17.2 | 17.1 | 14.9 | 11.4 | 8.0 | 5.6 | 10.4 °C |
| S.D. | 1.2 | 1.2 | 1.2 | 0.9 | 0.9 | 0.7 | 1.0 | 1.0 | 0.7 | 0.8 | 0.8 | 1.3 | 0.4 |

Soil types are sand over red sandstone at Ross-on-Wye and clay at Cardiff which should lead to slight relative warming at Cardiff in winter. Over the period of the averages, Cardiff is, in fact, warmer than Ross-on-Wye - especially in winter - and with similar standard deviations one would expect the same order of departures from average at the two sites.

However, over the last few years, differences between Ross-on-Wye and Cardiff departures from average have shown a definite reversal of the normal during Spring and Summer so that Ross-on-Wye has been warmer than Cardiff.

Table 1 gives a week by week comparison of the two stations for the first 26 weeks of 1968 to 1970 inclusive (Week 1 commences on the Sunday nearest to January 1st in each year).

/Table 1

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Table 1

Departures from 1931-60 Average of 1 Foot Earth Temperatures at Cardiff and Ross-on-Wye °C

| Week | No. | 1970 C | 1970 R | 1970 (C-R) | 1969 C | 1969 R | 1969 (C-R) | 1968 C | 1968 R | 1968 (C-R) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | -1.7 | -2.3 | +0.6 | -0.3 | -1.6 | +1.3 | +0.9 | -0.2 | +1.1 |
| | 2 | +0.4 | +0.7 | -0.3 | +0.4 | +0.1 | +0.3 | -0.7 | -1.4 | +0.7 |
| Jan | 3 | +1.6 | +1.8 | -0.2 | +1.0 | +1.2 | -0.2 | +1.3 | +1.4 | -0.1 |
| | 4 | +1.7 | +1.2 | +0.5 | +1.9 | +2.4 | -0.5 | +1.7 | +1.7 | 0.0 |
| | 5 | +1.1 | +0.3 | +0.8 | +2.5 | +2.6 | -0.1 | +1.7 | +1.4 | +0.3 |
| | 6 | +0.1 | -1.0 | +1.1 | +0.6 | 0.0 | +0.6 | +0.1 | -0.8 | +0.9 |
| Feb | 7 | -0.7 | -1.7 | +1.0 | -0.7 | -1.3 | +0.6 | 0.0 | -0.2 | +0.2 |
| | 8 | +0.4 | -0.2 | +0.6 | -2.1 | -2.8 | +0.7 | -0.9 | -1.7 | +0.8 |
| | 9 | -0.7 | -1.7 | +1.0 | -1.2 | -1.8 | +0.6 | -1.6 | -2.7 | +1.1 |
| | 10 | -1.2 | -2.6 | +1.4 | -1.8 | -2.3 | +0.5 | - | - | - |
| Mar | 11 | -0.6 | -1.0 | +0.4 | -1.7 | -1.7 | 0.0 | -0.5 | -0.5 | 0.0 |
| | 12 | -0.1 | -0.9 | +0.8 | -0.9 | -1.0 | +0.1 | -0.4 | -0.7 | +0.3 |
| | 13 | -0.9 | -1.4 | +0.5 | - | -4.7 | - | +0.3 | +0.7 | -0.4 |
| | 14 | -1.6 | -1.5 | -0.1 | -2.0 | -1.7 | -0.3 | -0.6 | -0.7 | +0.1 |
| Apr | 15 | -1.2 | -0.4 | -0.8 | -0.3 | -0.1 | -0.2 | -1.9 | -1.5 | -0.4 |
| | 16 | -0.4 | +0.1 | -0.5 | -1.4 | -1.0 | -0.4 | - | - | - |
| | 17 | -1.1 | -0.7 | -0.4 | -1.7 | -1.1 | -0.6 | +0.1 | +1.5 | -1.4 |
| | 18 | 0.0 | +1.6 | -1.6 | -1.8 | -1.2 | -0.6 | -0.7 | +0.7 | -1.4 |
| | 19 | +0.1 | +1.2 | -1.1 | -1.3 | -0.6 | -0.7 | -1.6 | -0.7 | -0.9 |
| May | 20 | -0.2 | +1.5 | -1.7 | +0.7 | +0.6 | +0.1 | -1.7 | -1.1 | -0.6 |
| | 21 | -0.2 | +1.4 | -1.6 | -1.5 | -0.7 | -0.8 | -2.4 | -1.9 | -0.5 |
| | 22 | +0.1 | +1.8 | -1.7 | -1.6 | -0.7 | -0.9 | -1.3 | +0.2 | -1.5 |
| | 23 | +0.7 | +2.8 | -2.1 | -2.0 | -0.9 | -1.1 | -1.0 | +1.1 | -2.1 |
| Jun | 24 | -0.1 | +1.7 | -1.8 | -1.7 | +0.7 | -2.4 | -0.9 | +0.9 | -1.8 |
| | 25 | -0.3 | +0.9 | -1.2 | +1.2 | +0.3 | -1.5 | -0.6 | +1.2 | -1.8 |
| | 26 | -1.4 | -0.8 | -0.6 | -1.8 | -0.5 | -1.3 | -1.3 | -0.8 | -0.5 |

Cardiff mainly colder than Ross

Cardiff mainly warmer than Ross

These data suggest that some change in site or exposure at either Cardiff or Ross-on-Wye has affected the comparative level of earth temperatures and examination of station files and inspection reports shows the possibility of both being effective.

The earth thermometers at Cardiff were moved some 10 feet from the SE to SW corner of the enclosure and photographs taken during the 1969 inspection show grass of 12 to 18 inches long in the enclosure. It is probable that the long grass would have sufficient insulating effect to explain the relative coldness in summer and warmth in winter at Cardiff.

The level of disturbance of earth temperature values in this instance raises more general questions on the validity of earth temperatures from stations with widely differing standards of maintenance (and perhaps continuity of observers) and an examination of monthly data for Cardiff, Ross-on-Wye and Long Ashton has been made for the years 1931-69.

Cardiff has had minor site changes, a few changes in observers and at least one period of poor maintenance.

Ross-on-Wye has had the same site, observer and consistently high standard for many years.

/Long Ashton

Long Ashton has had one site change of some 250 yards, a few changes in observer, increasing protection effects as glass houses have been built nearby and, at times, rather less than the ideal standard of maintenance (e.g. long grass).

For any given month, the mean difference in earth temperatures between two sets of observations at nearby sites, will be reasonably constant[1]. This allows missing data to be estimated with a probable accuracy of $\pm 0.25^{\circ}C$ for a monthly mean and $\pm 0.1^{\circ}C$ for 30-year normals. It is also the justification for the use of departures from average as representative of areal differences (but not, of course, the actual temperatures, which may vary considerably over even a few tens of feet).

Smith[2] gives a method of checking the validity of earth temperatures by plotting $(\bar{\Delta} - \Delta_i)$ on a time base graph where:-

$\bar{\Delta}$ = difference between monthly averages - preferrably over 10 years - of two stations.

$\Delta_i$ = individual differences between monthly means.

Where both stations are recording valid temperatures, the curve should show random fluctuations about the zero line - probably not exceeding $\pm 0.5^{\circ}C$. Any increase in amplitude, shift of axis or any suggestion of regular, periodic variation must raise suspicions about the data from one or other of the stations.

In this instance, it is assumed that Ross-on-Wye data are reliable and plots of $(\bar{\Delta} - \Delta_i)$ for Ross-on-Wye - Cardiff at 1 foot and 4 feet and of Ross-on-Wye - Long Ashton at 1 foot for the years 1931-69 are shown in figures 1 to 3 respectively.

In view of doubts as to when (if at all) data from all three stations were consistently reliable, $\bar{\Delta}$ has been taken as the difference between the 1931-60 normals.

Note that differences are taken (Ross-Cardiff) and $(\bar{\Delta} - \Delta_i)$; a positive deviation indicates too high temperatures at Cardiff and vice versa.

A number of points arise from the study of these curves:-

Figure 1 (Ross-Cardiff at 1 foot)

1. 1931-37 shows the normal random variations although one or two individual monthly differences are rather large (e.g. August and September 1933).

2. 1938-40 shows a tendency to a sinusoidal curve with summer maximum and winter minimum.

3. The pattern of 1938-40 is reversed in 1942-45 with a very marked spring minimum in 1944.

4. 1948-50 shows a general drop in the axis of variation.

/5.

5. 1951-54 again shows sinusoidal variation with summer maximum.

6. 1955-59 is again the normal random variation but with a gradual upward trend in the axis.

7. 1960-69 shows a generally sinusoidal pattern with summer maxima and with a marked increase in amplitude after 1966.

Figure 2 (Ross-Cardiff at 4 feet)

1. 1931-50 shows generally sinusoidal variation with summer maxima up to 1939 and summer minima after 1941.

2. After 1950 the variation is mainly random but with a few months outside the $\pm 0.5^{\circ}$C range. Occasional summer maxima occur (1956, '58, '60 and '65) and there appears to be a downward trend from 1965 onwards. The 1958 summer maximum - almost $2^{\circ}$C too warm - is particularly strange in that the warming persists to varying degrees over 5 months but the warming effect is hardly apparent in the 1 foot temperatures.

Figure 3 (Ross-Long Ashton at 1 foot)

Variation is rather more erratic than in figures 1 and 2 although some regular fluctuations are evident. Several individual monthly values appear to need investigation - especially December 1946 and 1954. These are probably faults in the Long Ashton data since the Ross-Cardiff plot did not show any abnormal variations at that time.

Examination of past inspection reports suggest some points which might have a significant effect on the readings.

Cardiff

In 1936 the 4 foot thermometer was found to be at 3 ft 9 ins but this would probably have only very slight effect on the temperatures.

The site was moved about 250 yards westwards in 1937.

In 1952, photographs show the grass in the enclosure to be some 3 to 6 inches long.

In 1962 the earth thermometers had been moved (since the last inspection in 1957 but the exact date is not recorded) some 10 feet westwards.

In 1969 the grass was 12 to 18 inches long in the enclosure; the 4 foot earth thermometer was again at 3 ft 9 ins and read $0.8^{\circ}$F too high on test; there was water in the 4 foot tube but not in the 1 foot although there was some "rust" on the thermometer which was at 11 inches depth.

Long Ashton

In August 1950 the 1 foot bulb was lowered from 10 inches to 1 foot.

Photographs in 1954 show newly cut grass in the enclosure which was probably 6 to 9 inches long before cutting.

/In

In 1959 the site was moved 70 yards southwest. For a time the enclosure was largely bare soil following cultivation and reseeding.

In 1962 water was found in the 1 foot tube - leak repaired in July - and grass was 2 to 3 inches long.

In 1967 the 1 foot thermometer was found to be at 13 inches.

In 1969 rain was found to be entering the tubes through broken caps.

Glasshouses had been erected quite close to the enclosure to the north and northwest and further development of glasshouses has now necessitated a further change of site.

The separate and combined effects of these various factors on the earth temperatures are difficult to define but long grass must have an insulating effect leading to too low summer and too high winter temperatures at 1 foot depth and perhaps to a general cooling at greater depths. In terms of $(\Delta - \Delta_1)$ plot this would give a sinusoidal curve with summer maximum and winter minimum.

Shading by trees or buildings would at times have a similar effect although the times at which shading took place would also enter into the result.

Incorrect depth will result in summer warming and winter cooling if the thermometers are not deep enough and vice versa.

The effect of water in the tube is probably negligible in terms of monthly means although individual daily values (and possibly weekly means) may be significantly affected.

Conclusions

1. The changes in Cardiff temperatures over the last 3 to 4 years may be due to long grass but if so it suggests a continual low standard of maintenance. It is certain that the departures from average published in our summaries and data in MWR involving Cardiff earth temperatures must be very misleading.

2. Assuming the technique is valid and we accept say $\pm 0.5^{\circ}C$ as a reasonable limit of variation, then a good many suspect values occur in the 1931 to 1960 period and this in turn casts some doubt on the published normals.

The alternative conclusion is that differences in departures from average of earth temperatures over the normal distances between our observing stations (of the order of 20 miles in the better areas) are much greater and much more variable than is generally believed.

3. With the known wide variation in standards of maintenance of various stations, the probable variations in earth temperatures which result suggest a very close and critical examination of data and inspection reports is desirable before any firm conclusions are based on earth temperature differences.

/References

References

1. Meteorological Office: Averages of earth temperature for the British Isles. M.O. 665, p 9.

2. Smith, L P Final report of WMO Inter-regional seminar on tropical agrometeorology, Maracay, Venezuela, 15-28. 9. 1960. pp 32-34.

Any comments or suggestions on this paper should be sent to the author.

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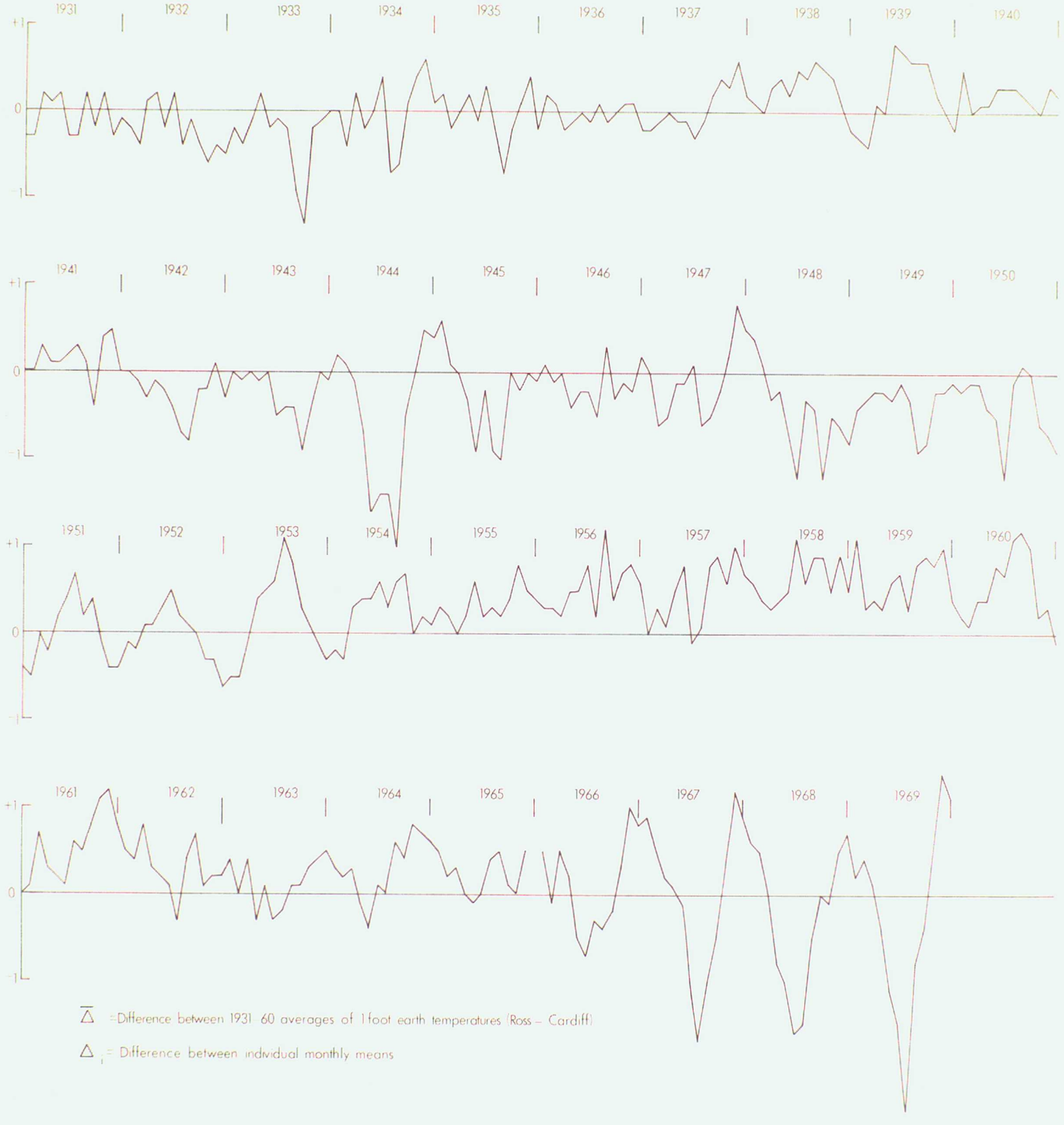
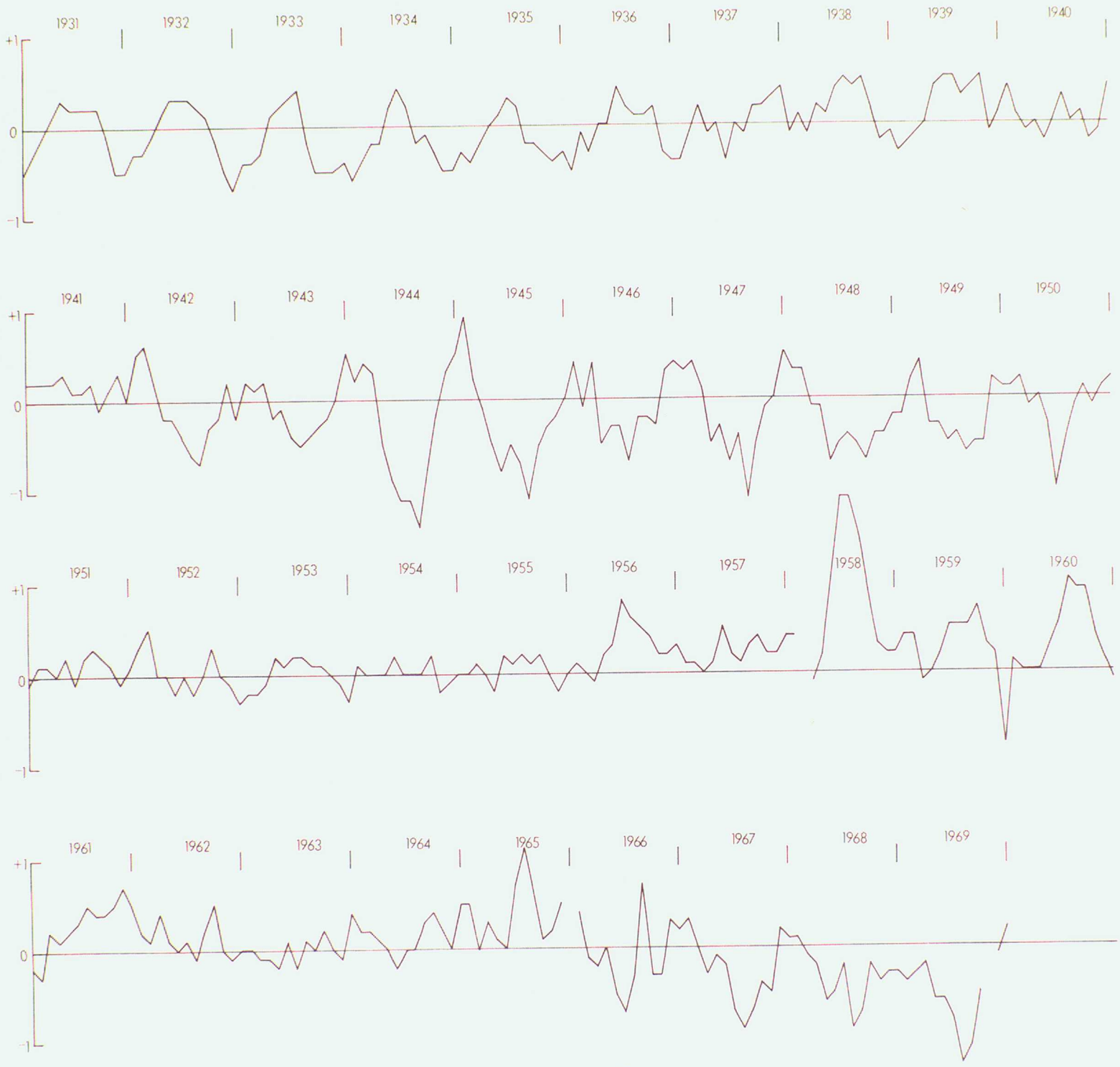
Fig 1 1 foot earth temperature ( $\overline{\Delta}$ – $\Delta_i$ ) ROSS-ON-WYE — CARDIFF




$\overline{\Delta}$ =Difference between 1931 60 averages of 1 foot earth temperatures (Ross – Cardiff)

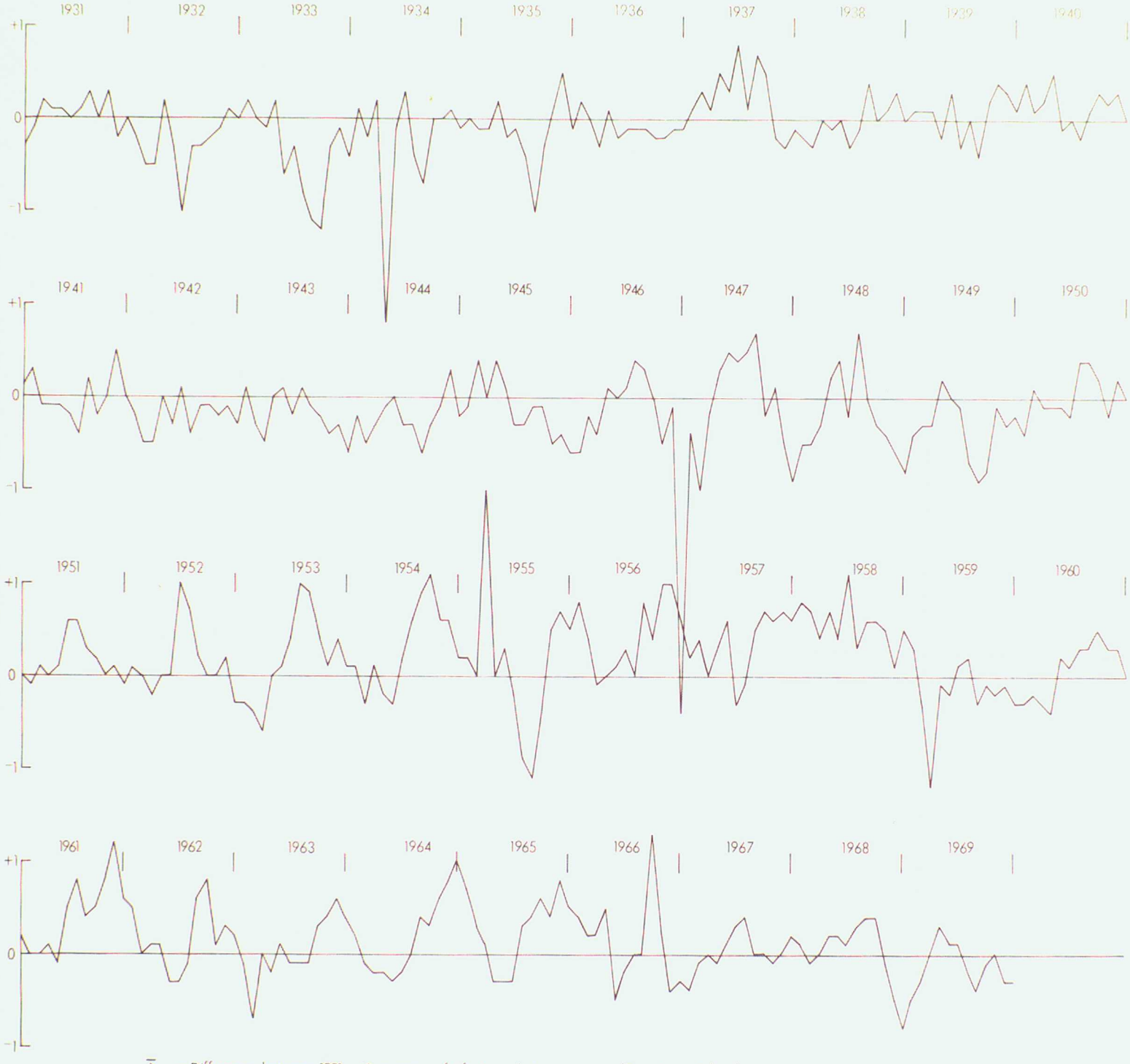
$\Delta_i$ = Difference between individual monthly means

Fig 2 4 foot earth temperature ($\bar{\Delta} - \Delta_i$) ROSS-ON-WYE — CARDIFF




$\bar{\Delta}$ = Difference between 1931–60 averages of 4 foot earth temperatures (Ross–Cardiff)

Fig 3 1 foot earth temperature ( $\bar{\Delta}$ $\Delta_1$ ) ROSS-ON-WYE — LONG ASHTON




$\bar{\Delta}$ = Difference between 1931–60 averages of 1 foot earth temperatures (Ross–Long Ashton)